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by

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ABSTRACT

Detectable levels of Ra-226 (0.2 to 27.6 pCi/g), Ra-223 ($\leq$0.1 to 4.3 pCi/g) and Pb-210 (0.6 to 6.9 pCi/g) were measured in various species of vegetation growing on various uranium tailings in Elliot Lake. On the other hand levels of Th-232 ($\leq$0.1 pCi/g), Th-230 ($\leq$0.1 pCi/g) and Th-228 ($\leq$0.1 pCi/g) were near detection limits in the same vegetation samples. In tailings substrates, all radionuclides investigated were detectable: Ra-226 (8.8 to 552 pCi/g), Ra-223 (3.1 to 213 pCi/g), Pb-210 (5.4 to 441 pCi/g), Th-232 (1.6 to 15.4 pCi/g), Th-230 (4.9 to 62 pCi/g) and Th-228 (1.3 to 38 pCi/g).

Lower Th than Ra and Pb levels in tailings substrate were believed to be the cause for the relatively lower Th levels measured in vegetation when compared to Ra and Pb concentrations. No correlation was observed between the level of a given radionuclide in tailings and in the vegetation growing on that tailings.

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ABSORPTION DE RADIONUCLÉIDES PAR LES PLANTES CROISSANT SUR LES RÉSIDUS D'URANIUM, ELLIOT LAKE (ONTARIO)

par

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RÉSUMÉ

On a pu mesurer des niveaux appréciables de radionucléides comme le Ra-226 (0,2 à 27,6 pCi/g), le Ra-223 ($\leq$0,1 à 4,3 pCi/g) et le Pb-210 (0,6 à 6,9 pCi/g) dans diverses espèces de plantes qui croissent sur les résidus provenant des opérations de traitement de l'uranium à Elliot Lake. D'autre part, les niveaux de Th-232 ($\leq$0,1 pCi/g), Th-230 ($\leq$0,1 pCi/g) et Th-228 ($\leq$0,1 pCi/g) étaient perceptibles dans ce même échantillonage. L'examen des substrats des résidus a permi d'isoler tous les radionucléides: Ra-226 (8,8 à 552 pCi/g), Ra-223 (3,1 à 213 pCi/g), Pb-210 (5,4 à 441 pCi/g), Th-232 (1,6 à 5,4 pCi/g), Th-230 (4,9 à 62 pCi/g) et Th-228 (1,3 à 38 pCi/g).

On croit que la raison pour laquelle des niveaux de Th relativement moindres que les niveaux de Ra et Pb ont été observés dans les plantes lors de la comparaison des concentrations est que les substrats des résidus d'uranium ont une teneur moindre en Th qu'en Ra et Pb. On n'a pu faire la corrélation entre la teneur en espèces radioactives particulières des résidus et le niveau de ces mêmes espèces radioactives dans les plantes croissant sur ces résidus.

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INTRODUCTION

In Elliot Lake, Ontario, most of the inactive uranium tailings have been revegetated for the past seven years or so. Physically, the vegetation has provided a good control on wind and water erosion and has greatly improved the aesthetics of the waste sites. Chemically and biologically the vegetation interacts with the tailings material and some uptake of contaminants by the vegetation takes place. Radionuclide uptake by various plants at the Nordic tailings site in Elliot Lake has been studied by Moffett et al. (1), Cloutier, Davé et al. (2), and in various plant tissues and species by Davé et al. (3). There has been little work done on vegetation growing on other tailings locations. This report is an extension of the work described in reference (3). The objective of the present study has been to determine the levels of various radionuclides in different plant species from different tailings areas and to correlate them with those in the tailings substrate.

METHOD

Both tailings and vegetation samples were collected in Elliot Lake at the following tailings sites: Lacnor, Nordic Main, Nordic West Arm, Quirke, Spanish American, Stanrock and Williams Lake, see Fig. 1.

The vegetation samples consisted of the following: stems of white birch (Betula papyrifera Marsh), leaves of white birch, stems of trembling aspen (Populus tremuloides Michx), leaves of trembling aspen, mixed grass species and mixed legume species. All vegetation samples were washed first under tap water and then under distilled water. The samples were then dried (100°C).

A number of tailings samples (cores from 0 to 37 cm below surface of tailings) were collected at each site and then homogenized together to form a composite substrate sample from each location. Samples were then oven dried

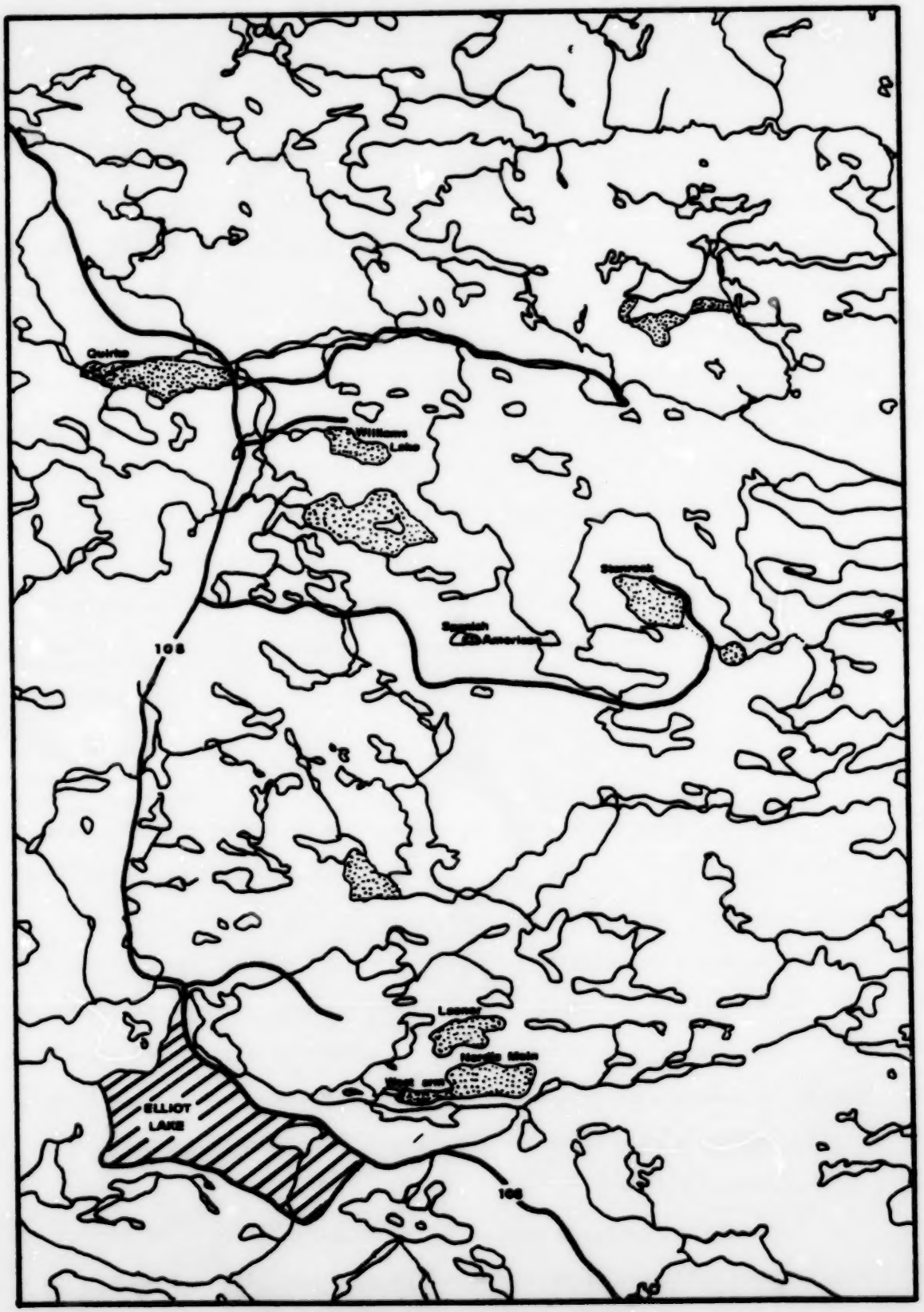

Fig. 1 - Location of study sites.

at 100°C.

Vegetation and substrate samples were then split into two parts. One part was wet digested and analyzed for Pb-210 by counting Bi-210 beta particles at equilibrium. The second part of each sample was ashed at 500°C, digested and subsequently analyzed for Ra and Th using the alpha spectroscopic technique. The details of sample preparation and analysis are described in reference (3).

RESULTS AND DISCUSSION

Levels of Ra-226 in tailings substrates varied between 8.8 to 522 pCi/g which is a range considerably higher than for any of the Th isotopes discussed below (Table 1). Detectable levels of Ra-226 (0.2 to 27.6 pCi/g) were measured in vegetation growing on tailings (Table 1). Therefore, it appears that Ra-226 levels were sufficiently elevated in Elliot Lake tailings to cause accumulation of this radioisotope in plants growing on the waste surface. These results agree with those of Moffett and Tellier (1), Cloutier et al. (2) and Davé et al. (3) who detected accumulations of Ra-226 in vegetation growing on Nordic uranium tailings.

Ra-223 levels varied between 3.1 to 213 pCi/g and $\leq$0.1 to 4.3 pCi/g in tailings substrates and vegetation, respectively (Table 1). Therefore, it can be said that in comparison to Ra-226, Ra-223 is present in lower concentrations in the Elliot Lake tailings which is in turn reflected by the lower Ra-223 levels measured in the vegetation growing at those sites.

Pb-210 levels in tailings were found to be next in importance after Ra-226 since samples had concentrations varying between 5.4 and 441 pCi/g. Because detectable levels of Pb-210 (0.6 to 6.9 pCi/g) were measured in vegetation growing on tailings (Table 1), Pb-210 was considered to be present in sufficiently high levels in tailings to cause a slight accumulation of the isotope within vegetation.

Table 1 - Radionuclide concentrations (pCi/g dry weight) in substrates and vegetation samples collected on various uranium tailings in Elliot Lake.

Element	Site	Substrate	Grass	Legume	White Birch Stem	White Birch Leaves	Trembling Aspen Stem	Trembling Aspen Leaves
Ra-226	Lacnor	136±6	11.5±0.7	7.0±0.5	-	-	-	-
	Nordic Main	227±8	18.8±0.9	6.4±0.4	-	-	-	-
	Nordic Main	245±9	-	-	14.0±0.8	27.6±1.0	4.0±0.4	2.7±0.2
	Nordic West Arm	296±9	3.9±0.3	0.2±0.1	-	-	-	-
	Nordic West Arm	522±14	-	-	17.1±1.0	25.3±0.8	2.3±0.2	3.4±0.3
	Quirke	11.8±0.8	8.4±0.5	3.5±0.3	-	-	-	-
	Spanish American	119±4	0.3±0.1	3.6±0.2	-	-	-	-
	Stanrock	406±11	-	-	6.4±0.2	13.5±0.6	1.9±0.3	2.2±0.2
	Williams Lake	8.8±0.8	8.2±0.5	1.9±0.3	3.5±0.2	6.0±0.5	3.0±0.4	0.9±0.2
Ra-223	Lacnor	42±3	0.7±0.1	0.4±0.1	-	-	-	-
	Nordic Main	64±3	3.3±0.3	1.3±0.2	-	-	-	-
	Nordic Main	55±4	-	-	3.9±0.5	≤0.1	0.9±0.3	0.6±0.3
	Nordic West Arm	96±4	0.7±0.1	2.6±0.4	-	-	-	-
	Nordic West Arm	213±7	-	-	1.7±0.4	3.2±0.3	0.5±0.1	0.9±0.2
	Quirke	4.6±0.6	0.4±0.1	0.3±0.1	-	-	-	-
	Spanish American	28±2	≤0.1	≤0.1	-	-	-	-
	Stanrock	140±5	-	-	1.8±0.1	4.3±0.4	1.5±0.4	1.9±0.3
	Williams Lake	3.1±0.3	0.4±0.1	0.3±0.1	0.4±0.1	0.7±0.2	0.3±0.2	≤0.1
Pb-210	Lacnor	95±5	2.3±0.7	2.9±0.7	-	-	-	-
	Nordic Main	197±9	1.2±0.7	1.1±0.7	-	-	-	-
	Nordic Main	228±10	-	-	2.8±0.8	1.6±0.8	0.7±0.6	0.8±0.7
	Nordic West Arm	245±11	0.6±0.6	0.6±0.6	-	-	-	-
	Nordic West Arm	441±19	-	-	6.9±0.9	2.5±0.8	0.6±0.6	1.0±0.7
	Quirke	8.0±1.2	5.3±0.8	2.2±0.7	-	-	-	-
	Spanish American	79±4	0.6±0.6	2.2±0.7	-	-	-	-
	Stanrock	305±13	-	-	1.9±0.7	2.1±0.7	0.6±0.6	3.1±0.8
	Williams Lake	5.4±1.1	0.9±0.6	0.6±0.6	1.3±0.7	0.8±0.7	0.6±0.6	0.7±0.6
Th-232	Lacnor	3.2±0.7	≤0.1	≤0.1	-	-	-	-
	Nordic Main	5.0±0.8	≤0.1	≤0.1	-	-	-	-
	Nordic Main	5.6±1.0	-	-	≤0.1	≤0.1	≤0.1	≤0.1
	Nordic West Arm	1.6±0.5	≤0.1	≤0.1	-	-	-	-
	Nordic West Arm	9.3±0.9	-	-	≤0.1	≤0.1	≤0.1	≤0.1
	Quirke	1.9±0.4	0.2±0.1	≤0.1	-	-	-	-
	Spanish American	12.3±1.3	≤0.1	≤0.1	-	-	-	-
	Stanrock	15.4±1.5	-	-	≤0.1	≤0.1	≤0.1	≤0.1
	Williams Lake	2.2±0.4	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1
Th-230	Lacnor	15±2	≤0.1	≤0.1	-	-	-	-
	Nordic Main	43±3	≤0.1	0.2±0.1	-	-	-	-
	Nordic Main	46±3	-	-	≤0.1	≤0.1	≤0.1	≤0.1
	Nordic West Arm	40±3	≤0.1	≤0.1	-	-	-	-
	Nordic West Arm	62±3	-	-	≤0.1	≤0.1	≤0.1	0.2±0.1
	Quirke	6.4±0.7	0.6±0.1	0.3±0.1	-	-	-	-
	Spanish American	19.1±1.7	≤0.1	≤0.1	-	-	-	-
	Stanrock	49±3	-	-	≤0.1	0.2±0.1	≤0.1	0.3±0.1
	Williams Lake	4.9±0.6	0.2±0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1
Th-228	Lacnor	2±1	≤0.1	≤0.1	-	-	-	-
	Nordic Main	11±2	≤0.1	≤0.1	-	-	-	-
	Nordic Main	7±2	-	-	≤0.1	≤0.1	≤0.1	≤0.1
	Nordic West Arm	3±2	≤0.1	≤0.1	-	-	-	-
	Nordic West Arm	6.1±1.3	-	-	≤0.1	≤0.1	≤0.1	≤0.1
	Quirke	1.3±0.6	≤0.1	≤0.1	-	-	-	-
	Spanish American	38±2	≤0.1	≤0.1	-	-	-	-
	Stanrock	21±2	-	-	≤0.1	≤0.1	≤0.1	≤0.1
	Williams Lake	2±1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1	≤0.1

Table 1 shows that although Th-232 levels in various tailings substrate varied between 1.6 to 15.4 pCi/g no detectable levels were found in plant tissues. Therefore, it would appear that Th-232 levels in Elliot Lake tailings are not high enough to cause detectable accumulation ($\geq$0.1 pCi/g) within vegetation growing on those waste sites.

Detectable levels of Th-230 were found to vary between 4.9 and 62 pCi/g (Table 1) in tailings substrates. On the other hand Th-230 in various plant species did not reach detectable levels in most samples (Table 1). Therefore, results indicate that accumulation of Th-230 in vegetation growing on uranium tailings in Elliot Lake is minimal.

Levels of Th-228 in various tailings substrates were found to vary between 1.3 and 38 pCi/g (Table 1). No detectable levels of Th-228 were measured in plant samples collected on uranium tailings (Table 1). Therefore, it can be said that accumulation of Th-228 in plants growing on Elliot Lake uranium tailings is undetectable.

Detectable levels of Ra-226, Ra-223 and Pb-210 were measured in vegetation growing on Elliot Lake uranium tailings while Th-232, Th-230 and Th-228 levels were all below detection limits in the same samples. This observation was attributed to lower Th than Ra and Pb levels measured in tailings substrates. The lower Th levels in tailings are believed to have resulted from leaching. Because Th isotopes are present in a more soluble form in tailings than Ra and Pb, Th was leached out to a greater extent than Ra and Pb in the acidic, high total dissolved solids (sulphate, iron, etc.) tailings porewater environment.

No correlation between isotope levels in tailings and isotope levels in vegetation was evident. This was believed to be due to the fact that radionuclide levels in substrate samples did not correctly reflect the levels of radioisotopes in the substrate on which the sampled vegetation was growing, i.e.,

much lower radionuclide concentrations in substrates of Quirke and Williams Lake when compared to other sites (site variations).

It was believed that a difference in the depth of the rooting zone of each vegetation sample could be at the origin of the latter discrepancy. For example, if the vegetation sampled at site A had a rooting zone extending to 50 cm in the tailings while the vegetation sampled at site B had roots extending to 10 cm below the tailings surface then sample A was exposed to a higher radionuclide uptake than sample B since radionuclide levels are higher at greater depth as discussed in a previous paper (3). Therefore, radionuclide levels within samples A and B should not be expected to correlate with radionuclide levels within tailings substrate samples collected to a certain depth from surface.

Although no correlation was found between radionuclide levels in tailings substrates and vegetation, it can be seen from Table 1 that vegetation had a narrower range of concentration than did the substrate (i.e., Ra-226 in vegetation varied between 0.3 and 27.6 pCi/g while Ra-226 in tailings varied from 8.8 to 552 pCi/g). These rather uniform isotope concentrations measured in vegetation could be indicating that the radionuclides are replacing a fraction of an essential element in the plants, the essential element being always present in the same concentration in a given plant species.

CONCLUSIONS

It can first be concluded that detectable levels of Ra-226 (0.32 to 27.6 pCi/g), Ra-223 ($\leq$0.1 to 4.3 pCi/g) and Pb.210 (0.6 to 6.9 pCi/g) were present in vegetation growing on uranium tailings in Elliot Lake. On the other hand levels of Th-232 ($\leq$0.1 pCi/g), Th-230 ($\leq$0.1 pCi/g) and Th-228 ($\leq$0.1 pCi/g) were undetectable within similar samples. In tailings substrates all radionuclides investigated had detectable concentrations: Ra-226 (8.8 to 522 pCi/g), Ra-223 (3.1 to 213 pCi/g), Pb-210 (5.4 to 441 pCi/g), Th-232 (1.6 to 15.4 pCi/g), Th-230 (4.9 to 62 pCi/g) and Th-228 (1.3 to 38 pCi/g).

The lower Th levels measured in tailings, when compared to Ra and Pb, were believed to be at the origin of the lower Th levels measured in vegetation. No correlation was evident between the concentration of a given radionuclide in tailings and in the vegetation growing on that tailings. This discrepancy was believed to have been caused by a lack of correlation between the depth of the rooting zone of the vegetation samples and the depth of the substrate core samples. Further analyses are planned in the near future to investigate this latter plenomenon in greater detail.

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